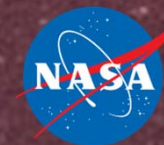




Diagnosing meteorological conditions associated with sprites and lightning with large Charge Moment Changes (CMC) over Oklahoma



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ABSTRACT

Sprites are a category of Transient Luminous Events (TLEs) that occur in the upper atmosphere above the tops of Mesoscale Convective Systems (MCSs). They are commonly associated with lightning strokes that produce large charge moment changes (CMCs). Synergistic use of satellite and radar-retrieved observations together with sounding data, forecasts, and lightning-detection networks allowed the diagnosis and analysis of the meteorological conditions associated with sprites as well as large-CMC lightning over Oklahoma. One goal of the NASA-funded effort reported herein is the investigation of the potential for sprite interference with aerospace activities in the 20-100km altitude range, including research balloons, space missions and other aviation transports.

METHODOLOGY

Radar and lightning data for study cases were analyzed using a software programmed in the Interactive Data Language (IDL) on the Relampago workstation at the NSSTC.

❖CHARGE MOMENT CHANGE NETWORK (CMCN)

Charge moment change is defined as:

$$\Delta M = Z \cdot Q(t)$$

Where Z (km) is the altitude from which the charge is lowered to ground and Q(t) (C) is the amount of charge lowered and as a function of time. Large CMC discharges (≥ 75 C km) were mapped onto radar reflectivity mosaics.

❖NATIONAL LIGHTNING DETECTION NETWORK (NLDN)

The NLDN consists of remotes and ground-based sensing stations located across the United States that instantaneously detect the electromagnetic signals given off when lightning strikes the earth's surface. Flash-level NLDN data were analyzed to examine the CGs characteristics of storms producing negative or positive sprite-class lightning.



Figure 1. The NLDN was used to geolocate strokes with reported impulse (ICMC) values.

❖OKLAHOMA LIGHTNING MAPPING ARRAY (OKLMA)

The Oklahoma Lightning Mapping Array (OKLMA) provides three-dimensional mapping of very high frequency (VHF) radiation from lightning.

❖NMQ NATIONAL RADAR MOSAICS (NMQ)

The National Mosaic & Multi-Sensor QPE (NMQ) works using radar data from the Weather Surveillance Radar 1988 Doppler (WSR-88D), the result is to obtain 3-D mosaics of reflectivity for the entire United States at 5-min intervals.



Figure 2. The NMQ-3D mosaic domain and computational tiles

❖RADAR, SATELLITE IMAGERY, SOUNDING AND PHOCAL FORECASTS



- Archive imagery from Mesoscale and Microscale Meteorology (MMM), a division of NCAR.
- PhOCAL is a field 2013 campaign to obtain high-speed video of sprites and their parent within an LMA. Forecast for 30 March 2012 study-case were not available.
- Atmospheric sounding data, provided by University of Wyoming, were taken from the closest site.

CASE STUDY RESULTS

I

30 March 2012

Sprite capture time: 05:18:51 UTC

- ✓ Radar – strong convective core in western OK
- ✓ Surface – OK affected by a cold front. Severe thunderstorm warning issued at 5:30 UTC.
- ✓ Upper Air 500hPa – at 12:00 UTC cloudiness dissipated.
- ✓ IR – cloud tops temperatures ranging between -50 °C and -64 °C.

II

Sounding Data-30 March 2012

Time (UTC)	RH (%)	LCL (hPa)	CCL (hPa)	LFC (hPa)	LI (°C)	CIN (J/kg)	CAPE (J/kg)	EQ (hPa)
00:00	56	819.3	740	653.1	-5.3	-166	1592	225
12:00	80	936.8	850	740	-6.5	-28.4	2474	219

31 May 2013

Monitor the entire duration of multiple supercells the afternoon of March 31st, especially when El Reno Tornado occurred at 23:03 UTC.

- ✓ Radar – heavy convective line in mid OK. Reflectivity reach over 70dBZ.
- ✓ Surface – OK affected by a trough. Tornado warning issued since 20:30 UTC until early June 1st.
- ✓ Upper Air 500hPa – strong wind flow around 20.57 m s⁻¹.
- ✓ IR – storm top temperature ranging <-65 °C.

Sounding Data- 31 May 2013

Time (UTC)	RH (%)	LCL (hPa)	CCL (hPa)	LFC (hPa)	LI (°C)	CIN (J/kg)	CAPE (J/kg)	EQ (hPa)
12:00	93	924	755	677.2	-4.0	-243	2856	180.9
00:00*	73	876.9	760	711.8	-6.5	-120	3018	M**

**Missing *June 1st sounding data

III

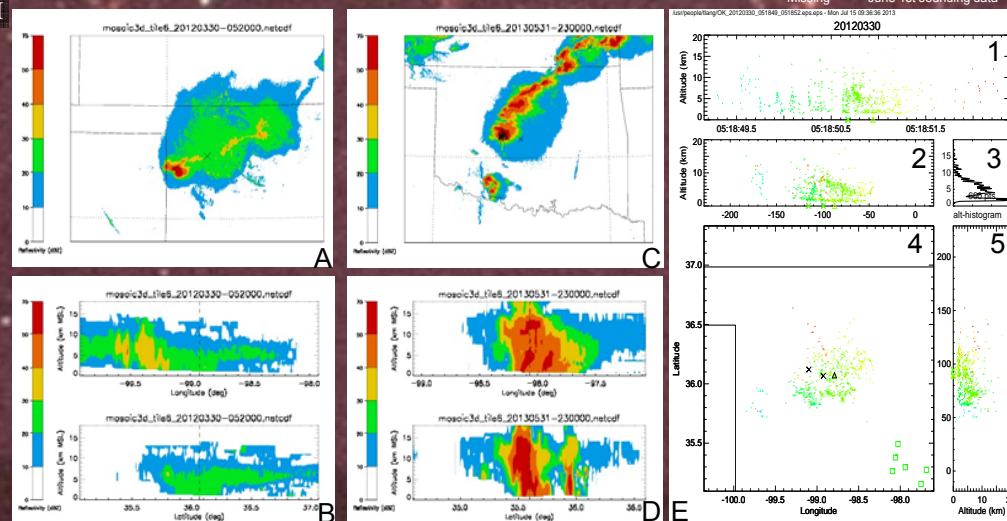


Figure 3. (A) 30 March 2012 and (C) 31 May 2013 shows composite radar reflectivity and large CMC (>75 C km) discharges over OK (positive are X symbols and negative are triangle symbols). (B) and (D) represent vertical cross section of the sprite capture location (B) and for the El Reno Tornado event (D). (E) 30 March 2012 observed lightning flash that originated at about 05:18:49 UTC. (1) Altitude (km) versus Time (s), (2) Altitude (km) versus longitude(km), (3) Normalized altitude (km) histogram of Very High Frequency (VHF) sources, (4) Latitude (km) versus Longitude (km), and (5) latitude (km) versus altitude (km). Color coding indicates elapsed time.

CONCLUSION

- ✓ 30 March 2012 and 31 May 2013 storms formed in moist environments with high CAPE and negative LI values.
- ✓ 30 March case, large CMC stroke in the stratiform of the storm produced sprite. Flash originated in convection.
- ✓ 31 May case, during the tornado development CGs were produced lots of large CMC discharges.

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